

Latin-to-Balinese Script Transliteration Method on Mobile Application: A Comparison

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ABSTRACT

Balinese script writing, as one of Balinese cultural richness, is going to extinct because of its decreasing use. This research is a way to preserve it through collaboration between Computer Science and Language discipline that focused on accuracy comparison of Latin-to-Balinese script transliteration method on mobile application as a ubiquitous learning media. From few research in this area, there are only two existing methods to be compared, i.e. each on Android mobile application that were called Belajar Aksara Bali (BAB), and Transliterasi Aksara Bali (TAB). The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa. Through the experiment, TAB has outperformed BAB since TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases. This research contributes on a comprehensive accuracy comparison analysis of Latin-to-Balinese script transliteration method, specifically on mobile application, since there is no such study. This research also contributes on those methods improvement possibility. In the future, this research can be used as a reference for improvement of any Latin-to-Balinese script transliteration method by taking care on thirteen kind of special words that were found during this comparison study.

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1. INTRODUCTION

The Balinese script, natively known as Aksara Bali or Hanacaraka, is an alphabet used in the Bali Island, Indonesia. It commonly used for writing the Austronesian Balinese language, Old Javanese, and the liturgical language Sanskrit [1]. The script is a descendant of the Brahmi script, and so has many similarities with the modern scripts of South and Southeast Asia. The Balinese script, along with the Javanese script, is considered the most elaborate and ornate among Brahmic scripts of Southeast Asia [2].

Though everyday use of the script has largely been supplanted by the Latin alphabet [3], the Balinese script has significant prevalence in many of the island's traditional ceremonies and is strongly associated with the Hindu religion. The script is mainly used today for copying lontar or palm leaf manuscripts containing religious texts [2].

Based on Indonesia News Agency [3], the less use of the Balinese script has caused concern over the threat of the extinction. As Stern [4] said that saving the language can be done by cultural, political, and economic approach, another approach was taken, i.e. technological approach, by this research that

focused on accuracy comparison of Latin-to-Balinese script transliteration method on mobile application, as it eases people by providing handy transliteration learning by offline on mobile device (no Internet connection needed). Transliteration itself is the conversion of a text from one script to another [5] and is one aspect of Balinese script writing. There are only two existing methods to be compared, i.e. methods on Android mobile application that were called Belajar Aksara Bali (Learning Balinese Script) [6], and Transliterasi Aksara Bali (Balinese Script Transliteration) [7]. These two methods belong to a few detected research in Latin-to-Balinese script transliteration. The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as a project script committee related to the proposal by Eversen and Suatjana [1] for encoding the Balinese script in ISO.

Not so many references in this research area. A work related to the same object, i.e. Balinese script, was conducted by Sudana et al. [9] but their work is on Augmented-Reality-based learning media application that was focused on learning on how to write Balinese script. On Latin-to-Balinese script transliteration research area, Sartini et al. [10] has developed a text-to-digital-image converter method. The output is the Balinese script represented by using pre-collected images that were captured from Bali Simbar font [11] display at word processor. Arimbawa et al. [12] has developed a Latin-to-Balinese script transliteration method where the output Balinese script pattern was configured to be written by the robotic system.

2. BALINESE SCRIPT

According to Narendra [13], Balinese script complex behaviours demands complex rendering, includes: 1) Reordering and splitting. Some characters may have more than one separated glyph; 2) Various placement and shape of diacritics based on character context; 3) Contextual shaping which means glyph selection for character is determined by its neighbour character. There are various shape and position of a rendered character located above or below the other character; and 4) Complex ligature construction that was represented by new glyph as a substitution or composition of several glyphs.

Table 1 no. 1–3 shows several Balinese syllables, i.e.: 1) *ba* (U+1B29 Balinese letter *ba*); 2) *be* that comes from *ba* using *pangangge suara e* (U+1B3E Balinese sign *taling*). *Pangangge suara* is Balinese vowel sign attached to a syllable. According to Simpen [14], *taling* is placed on the left of the syllable so that it is appeared as if it is written first and then followed by *ba*. Actually, *taling* is written later which then change the sound of *ba*. This case shows Balinese complex behaviour that requires reordering; and 3) *bo* that comes from *ba* using *pangangge suara o* (U+1B40 Balinese vowel sign *taling tedung*). Separated *taling* and *tedung* is written before and after the syllable, respectively. This case shows Balinese script complex behaviour that requires reordering and character splitting. *Taling tedung* is also an example of a character that has more than one separated glyph.

Table 1 no. 4–7 shows various placement and shape of diacritics based on character context, i.e.: 4) *di* that comes from *da* (U+1B24 Balinese letter *da*) using *pangangge suara i* (U+1B36 Balinese vowel sign *ulu*); 5) *ding* that comes from *da* using *i* and *pangangge tengenan ng* (U+1B02 Balinese sign *cecek*). *Pangangge tengenan* is Balinese final consonant. *Ulu* at *di* was placed in the middle above character *da*, while *ulu* at *ding* was shifted slightly by *cecek*; 6) *dě* that comes from *da* using *pangangge suara ě* (U+1B42 Balinese vowel sign *pepet*); and 7) *děr* that comes from *da* using *ě* and *pangangge tengenan r* (U+1B03 Balinese sign *surang*). *Pepet* at *dě* was placed in the middle above character *da*, while *pepet* at *děr* not only was shifted slightly by *surang* but also become smaller to make width of *pepet surang* equal to character *da* below them.

Table 1. Complex behaviour of Balinese script

| No | Latin | Balinese | No | Latin | Balinese | Gantungan |
|----|-------|---|----|-------------------------------|--|---|
| 1 | ba |  | 7 | děr |  | |
| 2 | be |  | 8 | kra (using gantungan ra) |  |  |
| 3 | bo |  | 9 | skra (using gantungan ra) |  |  |
| 4 | di |  | 10 | krya (using gantungan rya) |  |  |
| 5 | ding |  | 11 | na + ā = nā |  | |
| 6 | dě |  | 12 | ra + ya = rya |  | |

Table 1 no. 8–10 show various forms of glyph that represent *gantungan* of Balinese syllables *ra* (U+1B2D Balinese letter *ra*). This *gantungan* is also called *cakra* or *guwung*; 8) *kra* that comes from *ka* (U+1B13 Balinese letter *ka*) using *gantungan ra*; 9) *skra* that comes from *sa* (U+1B32 Balinese letter *sa*) and *ka* using *gantungan ra*; and 10) *krya* that comes from *ka* using *gantungan rya* which is combination of *gantungan ra* (the third *cakra*) and *gantungan ya* (see Table 1 no. 12). The shape of glyph of *cakra* on *kra* (the first *cakra*) is narrower than the shape of glyph of *cakra* on *skra* (the second *cakra*). Besides, glyph is written below *ka* at the end of the first *cakra*, while glyph is written beside *ka* at the end of the second *cakra*. This case shows the Balinese script complex behaviour that some characters require glyph selection based on character context. Also, the third *cakra* shows the Balinese script complex behaviour on ligature construction.

Table 1 no. 11–12 show ligatures construction that one example was described above (Table 1 no. 12). Other case, i.e. *nā* that comes from *na* (U+1B26 Balinese letter *na*) that was followed by *pangangge suara ā* (U+1B35 Balinese vowel sign *tedung*).

3. RESEARCH METHOD

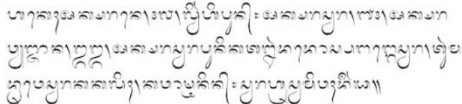
The accuracy comparison of Latin-to-Balinese script transliteration method was conducted on the only two existing methods on mobile application that were called Belajar Aksara Bali [6], and Transliterasi Aksara Bali [7]. The comparison was based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as shown by Table 2. Some of those examples (cases) referred to Simpen [14][15]. Not all of the rules can be tested independently without example, like the appended form of eighteen basic syllables at case 1–18, since provided examples are limited (case 19–25). Table 3 shows provided sentence and its transliteration for the case sixteen (word boundaries and line break rules) at Table 2.

Table 2. Testing cases

| No. | Case | Remark | No. | Case | Remark |
|-----|----------------|---|-----|--------------------------------------|--|
| 1 | 1-18 19-25 | Table 1* basic syllables (no. 1-18) Table 1* examples: word <i>Bakta</i> (bring) ... <i>Krama</i> (member) | 9 | 86-87 | Holy symbol <i>Ongkara</i> examples: word <i>Om Swastiastu</i> (May God blesses you) ... <i>Om Śanti, Śanti, Śanti, Om</i> (May peace be everywhere) |
| 2 | 26-34 | Table 2* vowel signs examples: word <i>Kadep</i> (sold) ... <i>Dwi</i> (two) | 10 | 88-89 | Table 9* miscellaneous syllables (no. 1-2) |
| 3 | 35-44 45-51 | Table 3* independent vowels (no. 1-10) Table 3* examples: word <i>Aksara</i> (alphabet) ... <i>Om</i> (symbol of God) | 11 | 90-99 | Table 10* the digits (digit: 0 - 9) |
| 4 | 52-55 56-57 | Table 4* illegal combination of syllable - vowel signs (no. 1-4) Table 4* examples: word <i>Talér</i> (also) ... <i>Kérèng</i> (eat a lot) | 12 | 100-107 | Table 11* punctuations: name <i>Carik</i> (a comma) ... Double Quotes |
| 5 | 58-62 | Table 5* semi vowels examples: word <i>Pak Raman</i> (Mr. Raman) ... <i>Briag</i> (laughter) | 13 | 108-113 114-115 116 117-124 | Some variation of usages. Combination of independence vowel <i>a</i> <i>kara</i> with vowel signs: vowel <i>i</i> ... <i>o</i> Pairing of <i>pa kapal</i> with <i>suku</i> or <i>suku ilut</i> : syllable <i>pu</i> ... <i>phu</i> Romanization of the inherent sound: word: <i>Sekala</i> (real) Usage of <i>pangangge aksara</i> : word <i>Samping</i> (side) ... <i>Tamblang</i> (a village's name) |
| 6 | 63-71 72-78 | Table 6* <i>aksara swalalita</i> (no. 1-9) Table 6* examples: word <i>Gapitri</i> (chain) ... <i>Laghu</i> (low tone in singing) | 14 | 125-146 | Table 13* <i>ligatures</i> (No. 1-22) |
| 7 | 79-83 | Table 7* sound killers examples: word <i>Cengceng</i> (a musical instrument) ... <i>Kapal</i> (ship) | 15 | 147-150 | Abbreviations example: word Bank <i>Pembangunan Daerah Bali</i> (Development Bank of Bali Province) ... <i>Ba Pa Da Bali</i> (BPD Bali) |
| 8 | 84-85 | Table 8* miscellaneous signs examples: word <i>Mang</i> (a holy letter) ... <i>Siddham</i> (perfect) | 16 | 151 | Word boundaries and line break rules |

*refer to table number at Sudewa [8]

Table 3. Provided sentence and its transliteration

| No | Script | Example |
|----|----------|---|
| 1 | Latin | <i>Akeh aksarane, 47, luiripun: aksara suara, 14, aksara wianjana, 33, aksara suara punika talér dados pangangge suara, tur madréwe suara kakalih, kawastanin: suara hréswa miwah dirgha. (Many letters, 47, i.e.: vowels, 14, consonants, 33, those vowels also become vowel signs, and have two type of sounds, each was called: sound hréswa and dirgha)</i> |
| | Balinese |  |

4. RESULTS AND ANALYSIS

Experiment for accuracy comparison of Latin-to-Balinese script transliteration method on two existing methods Belajar Aksara Bali version 1.0 [6], and Transliterasi Aksara Bali version 0.0.2 [7] was conducted on Intel(R) Core(TM) i5-6200U CPU @ 2.30GHz platform with 8 GB RAM and Windows 7 64-bit Operating System. For the next reference in this paper, both methods were referred by their abbreviation, i.e. BAB and TAB, respectively. Since both methods were developed by using Android mobile platform, the testing was conducted by using Android Emulator with Nexus 5 platform and Nougat (Android 7.1.1) 32-bit Operating System.

The testing result was shown by Table 4, where column *Case* represents writing rule or example of Table 2 and column *Result* shows transliteration result whether correct (check mark) or incorrect (cross mark). Refer to Table 3,

Figure 1 shows sentence transliteration limitations or differences by BAB and TAB, while

Figure 2 shows the modified sentence (consists of uncommon words in writing) to get its transliteration result more precise.

Figure 1 shows replacement of character *ś*, *ē*, and *ṭ* by character *s*, *e*, and *t*, respectively, because of limitation on entering such characters on mobile virtual keyboard. Note that TAB provides additional keyboard for character *ś*. The result analysis was conducted by using Indrawan [16], as references in this research. Table 4 shows the testing results, where TAB has outperformed BAB. TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases.

Table 4. Testing results

| Case | Result | | Case | Result | | Case | Result | | Case | Result | | Case | Result | |
|------|--------|-----|------|--------|-----|------|--------|-----|------|--------|-----|------|--------|-----|
| | BAB | TAB | | BAB | TAB | | BAB | TAB | | BAB | TAB | | BAB | TAB |
| 1 | √ | √ | 32 | x | x | 63 | x | x | 94 | √ | √ | 125 | x | √ |
| 2 | √ | √ | 33 | x | x | 64 | x | √ | 95 | √ | √ | 126 | x | √ |
| 3 | √ | √ | 34 | x | √ | 65 | x | √ | 96 | √ | √ | 127 | x | √ |
| 4 | √ | √ | 35 | √ | √ | 66 | x | x | 97 | √ | √ | 128 | x | √ |
| 5 | √ | √ | 36 | x | √ | 67 | x | x | 98 | √ | √ | 129 | x | √ |
| 6 | √ | √ | 37 | √ | √ | 68 | x | x | 99 | √ | √ | 130 | x | √ |
| 7 | √ | √ | 38 | x | √ | 69 | x | √ | 100 | x | √ | 131 | x | √ |
| 8 | √ | √ | 39 | √ | √ | 70 | x | √ | 101 | x | √ | 132 | x | √ |
| 9 | √ | √ | 40 | x | x | 71 | x | √ | 102 | x | √ | 133 | x | √ |
| 10 | √ | √ | 41 | √ | √ | 72 | x | x | 103 | x | √ | 134 | x | √ |
| 11 | √ | √ | 42 | √ | √ | 73 | x | √ | 104 | x | √ | 135 | x | √ |
| 12 | √ | √ | 43 | √ | √ | 74 | x | x | 105 | x | √ | 136 | x | √ |
| 13 | √ | √ | 44 | √ | √ | 75 | x | x | 106 | x | √ | 137 | x | √ |
| 14 | √ | √ | 45 | x | x | 76 | x | x | 107 | x | √ | 138 | x | √ |
| 15 | √ | √ | 46 | x | x | 77 | x | x | 108 | √ | √ | 139 | x | √ |
| 16 | √ | √ | 47 | x | x | 78 | x | √ | 109 | √ | √ | 140 | x | √ |
| 17 | √ | √ | 48 | x | √ | 79 | x | √ | 110 | √ | √ | 141 | x | √ |
| 18 | √ | √ | 49 | x | x | 80 | √ | √ | 111 | √ | √ | 142 | x | √ |
| 19 | √ | √ | 50 | x | x | 81 | √ | √ | 112 | x | x | 143 | x | √ |
| 20 | √ | √ | 51 | x | x | 82 | x | x | 113 | x | x | 144 | x | √ |
| 21 | √ | √ | 52 | x | x | 83 | √ | √ | 114 | √ | √ | 145 | x | √ |
| 22 | √ | √ | 53 | x | x | 84 | x | x | 115 | x | √ | 146 | x | √ |
| 23 | √ | √ | 54 | x | x | 85 | x | x | 116 | x | x | 147 | x | x |
| 24 | √ | √ | 55 | x | x | 86 | x | x | 117 | √ | √ | 148 | x | x |
| 25 | √ | √ | 56 | x | x | 87 | x | x | 118 | x | x | 149 | x | x |
| 26 | x | x | 57 | x | x | 88 | x | x | 119 | x | x | 150 | x | x |
| 27 | x | x | 58 | √ | √ | 89 | x | √ | 120 | x | √ | 151 | x | x |
| 28 | √ | √ | 59 | √ | √ | 90 | √ | √ | 121 | x | x | | | |
| 29 | √ | √ | 60 | √ | √ | 91 | √ | √ | 122 | x | x | | | |
| 30 | √ | √ | 61 | √ | √ | 92 | √ | √ | 123 | x | x | | | |
| 31 | x | x | 62 | x | x | 93 | √ | √ | 124 | √ | x | | | |

Note: BAB = Belajar Aksara Bali; TAB = Transliterasi Aksara Bali

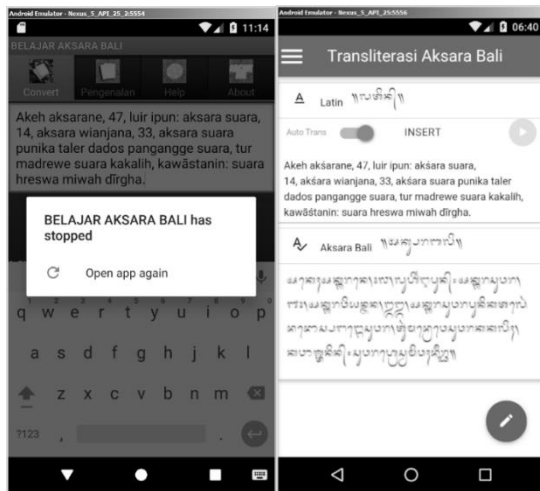


Figure 1 Sentence transliteration limitations by BAB (left); and TAB (right)

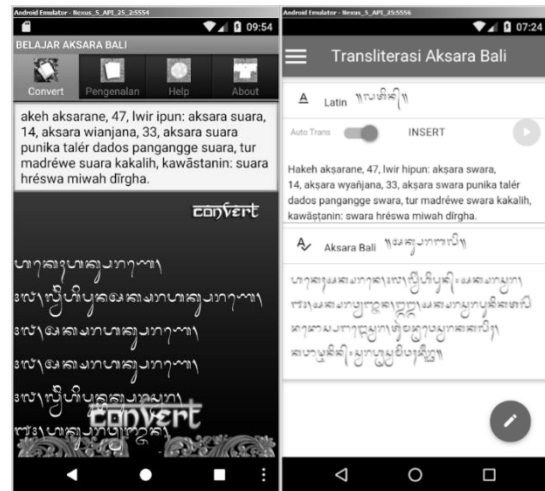


Figure 2 Modified sentence transliteration by BAB (left); and TAB (right)

Related to that result, the next sixteen analysis sections has been conducted based on sixteen case types on Table 2, respectively.

4.1. Basic syllables

Eighteen basic syllables (*akṣara wreṣāstra*) and provided examples (case on Table 4 no.1–25, or 4.1–4.25) were transliterated correctly by both of BAB and TAB. Each syllable has an appended form (*pangangge akṣara*) which kill the previous syllable sound. This appended form is called *gantungan* and *gempelan* if it hangs below and appearing after the previous syllable, respectively. Not all of this appended form can be tested independently, as described previously at Research Method section.

Case 4.1 need attention related to the more complex transliteration of syllable *a*, as a counterpart of syllable *ha*. BAB transliterated independently written syllable *a* the same as it transliterated independently written syllable *ha*, while TAB transliterated independently written syllable *a* the same as it transliterated independently written independent vowel *a* at case 4.35 (see next section 4.3). Actually, syllable *a* can be transliterated the same as syllable *ha* or independent vowel *a*. It depends on word that has syllable *a* at the initial position. If that word is a special word, for an example word *Akṣara* (letter) at case 4.45 (see next section 4.3), syllable *a* will be transliterated the same as independent vowel *a*. Otherwise, that word will be transliterated the same as syllable *ha*, for an example word *Angklung* (a musical instrument) at case 4.31 (see next section 4.2). For both BAB and TAB, the transliteration algorithm can be improved to handle those special words through word searching on *dictionary* (*hash table*) data structure that according to Cormen et al. [17] will give average *time complexity* $O(1)$ regardless of the amount of data (words) save inside this kind of data structure. As a note, the use of *dictionary* data structure was previously done by the authors for biometric data discriminator in [18]–[21]. If certain special word is found there, simply transliterate that word by using independent vowel. Unfortunately, there is still no research to know the precise list of those special words that influence the accuracy of developed transliteration system in general (neither do other special words on the next sections). However, through the implementation of the *dictionary* data structure, aggregation of known words belong to those special words can be done even the precise list of those special words still not known.

4.2. Vowel signs

Twelve vowel signs, as part of vowels (*akṣara suara*), are attached to syllables. They cannot be tested independently, as described previously at Research Method section. Some of provided examples (case 4.26–4.34) were transliterated incorrectly by BAB and/or TAB, i.e. word *Kādep* (sold), *Jéro* (house), *Angklung* (a musical instrument), *Daitya* (giant), *Patūt* (should be), and *Dwī* (two) at case 4.26–4.27, 4.31–4.34, respectively.

On case 4.26, word *Kādep* uses vowel *ā* as *tedong ligature* (see next section 4.14) where BAB was failed to transliterate it. Another aspect is that vowel *e* at reference word *Kādep* should be written by

using vowel *ě* (become *Kāděp*) since vowel sign *pepet* was used at reference transliteration result (like vowel *ě* at word *Jěro* at case 4.27). Both of BAB and TAB were failed to transliterate vowel *ě* but both of them provide a replacement vowel *é*. Actually word *Kāděp* and its variations (i.e. *Kādep*, *Kaděp*, and *Kadep*) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On case 4.27, both of BAB and TAB were failed to transliterate vowel *ě* of word *Jěro* but both of them provide a replacement vowel *é*, as described previously at word *Kādep*. Actually word *Jěro* and its variation (i.e. *Jero*) represent same kind of special words like previous word *Kāděp* since they refer to one meaning and should have same transliteration. Another aspect on TAB is that *tedong ligature* (see next section 4.14) should not be constructed on vowel *o* of word *Jěro* since it was not pronounced longer like vowel *ā* (that construct ligature) of word *Kāděp*. It seems that TAB constructs *tedong ligature* automatically if glyph *tedung* is found after regular form *ra* and no checking that glyph *tedung* and glyph *taling* precede that regular form *ra* actually construct *ro* not *rō*. This limitation must be taken care of for the algorithm improvement of TAB.

On case 4.31, vowel *A* of word *Angklung* was failed to be transliterated by both of BAB and TAB because of improper algorithm handling of uppercase vowel and incorrect usage of independent vowel, respectively. On case 4.32, both of BAB and TAB were failed to transliterate vowel sign *taleng repa ai* of word *Daitya* but TAB provide a replacement vowel *ê*. It related to diphthong *ai* that is pronounced as long vowel *ê*. Actually word *Daitya* and its variation (i.e. *Dêtya*) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.33, both of BAB and TAB were failed to transliterate vowel sign *suku ilut ū* of word *Patūt* but TAB provide a replacement vowel *ú*. On case 4.34, BAB was failed to transliterate vowel sign *ulu sari ī* of word *Dwī*. Actually word *Patūt* and its variation (i.e. *Patut*); and word *Dwī* and its variation (i.e. *Dwi*) represent same kind of special words like previous word *Kāděp* since each refer to one meaning and should have same transliteration.

4.3. Independent vowels

Ten independent vowels, as part of vowels (*akṣara suara*), are used at initial position of the word (case 4.35–4.51). Some of them and their provided examples were transliterated incorrectly by BAB and/or TAB, i.e. vowel *ā*, *ī*, *ū*, word *Akṣara* (letter), *Iṣwara* (God's name), *Upacāra* (ceremony), *Eka* (one), *Airlangga* (a Javanese king), *Ong* (a holy letter), and *Om* (symbol of God) at case 4.36, 4.38, 4.40, 4.42, and 4.45–4.51, respectively.

On case 4.35, 4.37, 4.39, and 4.41–4.43, independently written vowel *a*, *i*, *u*, *e*, *ai*, and *au* can be transliterated by using syllable *ha* with its vowel sign (BAB approach), or by using independent vowel (TAB approach). On case 4.36, 4.38, and 4.40, vowel *ā*, *ī*, and *ū* (using *tedong ligature*, see next section 4.14) was failed to be transliterated by BAB. TAB was failed to transliterate vowel *ū* but it provides a replacement vowel *ú* (see previous section 4.2). On case 4.42, independently written vowel *airsania ai* should be mapped to vowel *ê* for correct transliteration. Case 4.44 is basically the same as case 4.42 but on different independently written vowel *au* that should be mapped to vowel *ô* for correct transliteration by TAB (related to the diphthong *au* that is pronounced as the long vowels *ô*).

On case 4.49, word *Airlangga* also was failed to be transliterated by both of BAB and TAB because of improper algorithm handling of uppercase vowel and no *surang* was used for consonant *r*, respectively. On case 4.45, one aspect of word *Akṣara* has already been analysed (see previous section 4.1). Another aspect is that consonant *ś* of word *Akṣara* was failed to be transliterated by both of BAB and TAB but only TAB provides a replacement consonant *ṣ* (related to syllable *sa sapa*, see next section 4.6) to give correct transliteration. On case 4.46, word *Iṣwara* was failed to be transliterated by both of BAB and TAB. On BAB, lowercase vowel must be used to give correct transliteration result. On TAB, a replacement consonant *ś* was provided for consonant *ṣ* (related to syllable *sa saga*, see next section 4.6).

On case 4.47, word *Upacāra* was failed to be transliterated by BAB. Lowercase vowel must be used to give correct transliteration result. Actually word *Upacāra* and its variation (i.e. *Upacara*) represent same kind of special words like previous word *Kāděp* since they refer to one meaning and should have same transliteration. On case 4.48, word *Eka* was failed to be transliterated by BAB except by using lowercase vowel. On case 4.50, word *Ong* was transliterated incorrectly by both of BAB and TAB. It was constructed not only by independent vowel *o kara O* but also by using sound killer *ulu candra* (see next section 4.8), instead of *cecek* (see next section 4.7), to end inherent sound of syllable *nga*. On case 4.51, word *Om* was transliterated incorrectly by both of BAB and TAB. It was constructed

not only by independent vowel *o kara tedung Ô* but also by using sound killer *ulu candra* (see next section 4.8 and 4.9), instead of *adeg-adeg* (see next section 4.7), to end the inherent sound of syllable *ma*.

4.4. Syllable - vowel sign combination

Illegal combination of syllable - vowel signs happened on case where all of basic syllables (see previous section 4.1) can have any of vowel signs (see previous section 4.2), except *ra* and *la* that cannot have *ě* or *ô* appended to them. They must use regular form *ra repa* and *la lenga*, respectively (case 4.52–4.57). All of the cases were transliterated incorrectly by both of BAB and TAB, i.e. *rě, lě, lõ*, word *Talěr* (also), and *Kěrěng* (eat a lot). Common cause is a limitation on entering vowel *ě* on mobile application. However, both of BAB and TAB provide a replacement vowel *é*. Next analysis was based on this replacement vowel *é*.

On case 4.56 by TAB, syllable *lé* of word *Talér* was transliterated incorrectly by using illegal combination of syllable *la* and vowel sign *pepet* (to kill previous sound *a* of *la* and replace it with sound *é*), instead of using regular form *la lenga*. If word was written without *r*, *lé* was transliterated correctly. All of this inconsistency need to be taken care of for algorithm improvement. On case 4.57 by both BAB and TAB, syllable *ré* of word *Kěrěng* was transliterated incorrectly by using illegal combination of syllable *ra* and vowel sign *pepet* (to kill previous sound *a* of *ra* and replace it with sound *é*), instead of using regular form *ra repa*. On both BAB and TAB, if word was written without *ng*, *rě* was transliterated correctly. All of this inconsistency need to be taken care of for algorithm improvement. Actually word *Talěr* and its variation (i.e. *Taler*); and word *Kěrěng* and its variation (i.e. *Kereng*) represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.5. Semi vowels

Four semi-vowels (*arda suara*) attached to syllable, i.e. *guwung*, *suku kembang*, *gantungan la*, and *nania* for *ra*, *wa (ua)*, *la*, and *ya (ia)*, respectively. From all of provided examples (case 4.58–4.62), only case 4.62 was transliterated incorrectly by both of BAB and TAB, i.e. word *Briag* (laughter).

On case 4.62, word *Briag* should be transliterated by stacking together *cakra* and *nania*. On TAB, using *ya* (rather than *ia*) at word *Briag* gave correct transliteration result. Actually word *Briag* and its variation (i.e. *Bryag*) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.58 and 4.59, word *Pak Raman* and *Pakraman* were transliterated differently by BAB, and were transliterated the same by TAB. Both of transliteration approach are correct. On BAB, *ra* of word *Pak Raman* was transliterated by using semi-vowel *cakra*, while syllable *ra* of word *Pakraman* was transliterated by using basic syllable *ra* and preceded by sound killer *adeg-adeg* to form consonant *k* of word *Pakraman* (see next section 4.7). On TAB, both of those words were transliterated by using mechanism on word *Pak Raman* by BAB.

4.6. Akšara swalalita

Nine *akšara swalalita*, in addition to the eighteen basic syllables (see previous section 4.1), are used for writing Kawi (Old Javanese) word. All of these *syllables* and their provided examples were transliterated incorrectly by BAB. Some of them and their provided examples were transliterated incorrectly by TAB, i.e. *ṇa, ṭa* (syllable *ta tawa*), *ṣa* (syllable *sa saga*), *śa* (syllable *sa sapa*), word *Gaṇitri* (chain), *Partha* (man's name), *Jaṭayu* (a bird), *Bhiśama* (decree), and *Śiwa* (God's name) at case 4.63, 4.66–68, 4.72, and 4.74–4.77, respectively.

On case 4.63, and 4.66–68 by TAB, replacement syllables were provided, i.e. *ṇa, ṭa* (syllable *ta tawa*), *śa* (syllable *sa saga*), and *ṣa* (syllable *sa sapa*), respectively. The usage of those replacement syllables solve all of incorrectly transliterated words related to *akšara swalalita*. Actually, word *Gaṇitri* and its variation (i.e. *Ganitri*); *Jaṭayu* and its variation (i.e. *Jatayu*); *Bhiśama* and its variation (i.e. *Bhisama*); and *Śiwa* and its variation (i.e. *Siwa*) they represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.7. Sound killers

Four sound killers (*pangangge tengenan*), i.e. *cecek*, *surang*, *bisah*, and *adeg-adeg*, are used to end sound of a syllable and represent consonant *ng*, *r*, *h*, and others, respectively. *Adeg-adeg* is the default sound killer that appears after a syllable (other than syllable *nga*, *ra*, and *ha*). Their appended form of

these syllables cannot be tested independently, as described previously at Research Method section. Some of provided examples (case 4.79–4.83) were transliterated incorrectly by BAB and/or TAB, i.e. word *Cengceng* (a musical instrument) and *Karṇa* (ear) at case 4.79 and 4.82, respectively.

On case 4.79 by BAB, *cecek* should be constructed in the middle of word because word *Cengceng* has same vowels. On case 4.82 by TAB, there is no surang was used for consonant *r*, the same as word *Airlangga* (a Javanese king) at case 4.49 (see previous section 4.3), *Talēr* (also) at case 4.56 (see previous section 4.4) and Table 3, *Partha* (man's name) at case 4.73 (see previous section 4.5), and *dirgha* (long sound vowels) at Table 3. Inconsistency was shown since *surang* was only used for consonant *r* at the end of the word *Talēr* even though it can appear anywhere. This limitation must be taken care of for the algorithm improvement.

4.8. Miscellaneous signs

Two miscellaneous signs (part of *akṣara modre*), i.e. *ulu candra* and *ulu ricem*, are kind of sound killers (see previous section 4.7) that are used to write Sanskrit words, usually part of prayers. They are used to end the sound of a syllable and represent consonant *ng* and *m*, respectively (at previous section 4.7, their counterpart sound killer of *ng* and *m* is *cecek* and *adeg-adeg*, respectively). All of provided examples were transliterated incorrectly by both of BAB and TAB, i.e. word *Mang* (a holly letter) and *Siddham* (perfect) at case 4.84 and 4.85.

On case 4.84 by TAB, a replacement consonant *m̄* was provided for consonant cluster *ng* of word *Mang*. On this case, word *Mang* represent another kind of special words that there is still no research to know the precise list of them. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.85 by TAB, a replacement consonant *ś* and *m̄* were provided each for consonant *S* and *m* of word *Siddham*. On this case, word *Siddham* represent another kind of special words that there is still no research to know the precise list of them. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.9. Holy symbol

When independent vowel *au kara* (see previous section 4.3) met sound killer *ulu candra* (see previous section 4.8), the Romanization is not *Aung*, but *Om*. *Om* has a special name, i.e. *Oṃkara*, as a holy symbol (*akṣara modre*). The most notable sentences using *Om* are the greetings. All of provided examples (case 4.86–4.87) were transliterated incorrectly by both BAB and TAB, i.e. phrase *Om Swastistu* (May God blesses you) and *Om Śanti, Śanti, Śanti, Om* (May peace be everywhere) at case 4.86 and 4.87, respectively.

On case 4.86 by TAB, a replacemet independent vowel *o kara tedung Ô* for vowel *O* and replacemet consonant *m̄* for consonant *m* of word *Om* was provided. *Om* represent another kind of special words and the transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. Word *Swastistu* should be transliterated by stacking together *cakra* and *nanīa* (see previous section 4.5). By using *ya* (rather than *ia*) at this word, it gave correct transliteration result. Actually, word *Swastistu* and its variation (i.e. *Swastyastu*) refer to one meaning and should have same transliteration. On this case, they represent same kind of special words like word *Briag* (laughter) at case 4.62 (see previous section 4.5). On case 4.87 by TAB, a replacement consonant, i.e. consonant *ś*, was provided for consonant *Ś* of *Śanti* (related to syllable *sa saga*, see previous section 4.6).

4.10. Miscellaneous syllables

The existence of two miscellaneous syllables (that apparently borrowed from Javanese) in Balinese script is very rare (case 4.88–4.89). On case 4.88, syllable *cha* was transliterated incorrectly by both BAB and TAB. Syllable *cha* has no regular form. It is always paired with the normal form of syllable *ca*. On case 4.89, syllable *kha* was transliterated incorrectly only by BAB.

4.11. Digits

All of the digits (0–9) were transliterated correctly by BAB and TAB (case 4.90–4.99).

4.12. Punctuations

All of independently written punctuations (case 4.100–4.107) were transliterated incorrectly by BAB. By TAB, comma (,), period (.), less-than (<), period-0-period (.), greater-than (>), double greater-than (>>), and colon (;) sign was transliterated correctly become *carik* (case 4.100), *carik pareren* (case

4.101), *panten* (case 4.102), *pasalinan* (case 4.103), *pamada* (case 4.104), *carik agung* (case 6105), and *carik pamungkah* (case 4.106) sign, respectively. Double quotes (case 4.107) has the same sign (“). *Panten* and *pasalinan* each is used at the beginning and at the end of a letter, a story, or a verse. *Pamada* and *carik agung* each is used at the beginning and at the end of a religious text.

4.13. Some variation of usages

Some variation of usages includes: 1) Incorrect combination of independence vowel *a kara* (see previous section 4.3) and vowel signs (see previous section 4.2); 2) Special use of syllable *pa kapal* (see previous section 4.6) that is never attached to *suku* or *suku ilut* (see previous section 4.2); 3) Romanization of the inherent sound; and 4) The use of *pangangge aksara* (see previous section 4.1).

On first variation of usages, for any vowel sounds, there are independent vowel glyphs that are ready to be used. On case 4.108–4.111, incorrect combination of independence vowel *a kara* and vowel sign were shown by using *a kara* combined with *ulu*, *suku*, *taling*, and *taling-tedung*. None of those incorrect combination came up on BAB and TAB. On case 4.112–4.113, vowel sound *ě* and *ö* that don't have independent vowel form, should be written by using syllable *ha* combined with *pepet* and *pepet-tedung* at case 4.112 and 4.113, respectively. Vowel sound *ě* and *ö* were transliterated incorrectly by both of BAB and TAB.

On second variation of usages, *pa kapal* can be paired with any vowel signs but its shape is not the same as other syllables since its final stroke is not going down. Hence *suku* and *suku ilut* cannot be attached to *pa kapal* but they are can positioned below it. On case 5.114, syllable *pa* that was paired with *suku*, was transliterated correctly by BAB and TAB. On case 5.115, *pa kapal* that was paired with *suku*, was transliterated correctly only by TAB.

On third variation of usages, a stand-alone syllable has inherent sound that is always Romanized as *a* and it is common to a Balinese to pronounced an *a* at the end of a word as *ě*. On case 5.116, word *sekalě* (real) was transliterated incorrectly by BAB and TAB since there is transliteration difference with word *sekala*. For both of word, vowel *e* at reference word *sekala* should be written using vowel *ě* (become *sěkala*) since *pepet* was used at reference transliteration result. Actually, word *Sekala* and its variations (i.e. *Sekalě*, *Sěkala*, and *Sěkalě*) represent another kind of special word since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On fourth variation of usages, several provided examples of case 4.117–4.124 were transliterated incorrectly by BAB and/or TAB, i.e. word *Suksma* (thank you), *Ksatria* (warrior), *Strī* (wife), *Smerti* (books of Veda), *Utama* (primary), and *Dharma* (religion) at case 4.118–4.123, respectively. First four examples are called *pluta* which are very rare form of *gantungan* or *gempelan*, when a non semi-vowel acts like a semi vowel (see previous section 4.5). Last two examples are called *dwita* that have double consonant syllable, but actually a single sound.

On case 4.117, consonant *m* of word *Samping* (side) was transliterated correctly by both of BAB and TAB without using *adeg-adeg* in the middle of word. On case 4.118, consonant *k* of word *Suksma* was transliterated correctly by both of BAB and TAB without using *adeg-adeg* in the middle of word, but its consonant *ś* was failed to be transliterated by both of them. On case 4.119, consonant *ś* of word *Ksatria* was transliterated incorrectly by both of BAB and TAB. This case is the same as word *Suksma* at case 4.118. Another aspect on BAB, vowel cluster *ia* need to be written *iya* for correct transliteration. This is the case where vowel cluster *ia* was not transliterated by using vowel sign (see previous section 4.2) or by changing it first become *ya* (see next section 4.5). Actually, word *Ksatria* and its variations (i.e. *Ksatria*, *Ksatriya*, and *Ksatriya*) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1. On case 4.120, vowel sign *ulu sari ī* of word *Strī* was transliterated incorrectly by BAB. On case 4.121, vowel *e* at reference word *Smerti* should be written by using vowel *ě* (become *Směrti*) since *gantungan mě* was used at reference transliteration result. This *gantungan mě* of word *Směrti* was transliterated incorrectly by both of BAB and TAB, even both of them provide a replacement vowel *é* for vowel *ě*. On case 4.122, word *Utama* was transliterated incorrectly by both of BAB and TAB. On TAB, it need to be written as *Utthama* for correct transliteration. On case 4.123, word *Dharma* was transliterated incorrectly by both of BAB and TAB. On TAB, it need to be written *Dharmma* for correct transliteration. Actually, word *Utama* and its variation (i.e. *Utthama*); and word *Dharma* and its variation (i.e. *Dharmma*) represent another kind of special words since each refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.14. Ligatures

Ligature as one pen strokes of two glyphs is desirable but not mandatory form. *Tedung* form ligatures with certain syllables. *Suku* and *suku ilut* form ligatures with certain *gantungan* or *gempelan* (see previous section 4.1). On case 4.125–4.146, *tedung* ligatures were transliterated incorrectly by BAB.

4.15. Abbreviations

Three different scheme for abbreviations can be used in Balinese, i.e.: 1) The one endorsed by the government to abbreviate government institutions. The scheme is to follow the way the abbreviation pronounced in Indonesian language; 2) The one used by [15]. The scheme is to use the first syllable with all the vowel signs attached to it; or if it is an independent vowel, then the independent vowel itself is used; and 3) The one less commonly used, but somehow the shortest one. The scheme is to use only syllable or independent vowel.

On case 4.147–5.150, phrase *Bank Pembangunan Daerah Bali* (Development Bank of Bali Province) and all of its three abbreviation schemes were transliterated incorrectly by both BAB and TAB. Latin abbreviation of that phrase is *BPD Bali* and its three abbreviation schemes, i.e. *Be Pe De Bali*, *Ba Pe Da Bali*, and *Ba Pa Da Bali* at case 4.148–4.150, respectively. On all of abbreviations schema there are *cariks* (see previous section 4.12) between syllable and/or word that still cannot be accommodated by BAB and TAB since there is no way to differentiate between this abbreviation phrase with non-abbreviation phrase. On case 4.147, word *Bank* need to be written as *Bang* for correct transliteration. Since consonant *ng* has the same pronunciation with consonant *nk* (foreign sound), it was used for transliteration. On this case, word *Bank* represent another kind of special words and the transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

4.16. Word boundaries and line break rules

There are no spaces to separate words in Balinese script. In the old time of writing on dried palm leaves (it was called *lontar*), spaces were scarce and the “page setup” for *lontar* was always a thin landscape. The number of lines is small, with every space must be filled for optimal use. There was common practice to break the sentence at any places. On case 4.151, several words of sentence were transliterated incorrectly by BAB and/or TAB, i.e. *Akeh* (Many), *luir* (i.e.), *ipun* (a pronoun to previous word *akšara*), *suara* (vowel), *wianjana* (consonant), *madrēwe* (have), *kawāštanin* (called), *hrēswa* (short vowel), and *dirgha* (long vowel).

On word *Akeh* by BAB and TAB, vowel *A* was failed to be transliterated because of improper algorithm handling of uppercase vowel and incorrect usage of independent vowel (see previous section 4.1), respectively. On BAB, using lowercase vowel gave correct transliteration result, the same case on word *Angklung* (a musical instrument) at case 4.31 (see previous section 4.2). On TAB,

Figure 2 shows how word *Akeh* was simply modified become *Hakeh*, which is uncommon in writing but right in transliteration. On word *luir* by BAB and TAB, semi vowel *ua* (that construct *ui* by using vowel sign *ulu*) was transliterated incorrectly except it was written as *wa* (see previous section 4.5), as show by

Figure 2. On word *ipun* by TAB, vowel *i* was transliterated incorrectly because of incorrect usage of independent vowel (see previous section 4.1).

Figure 2 shows how word *ipun* were simply modified become *hipun*, which is uncommon in writing but right in transliteration. On word *suara* by TAB, semi vowel *ua* was transliterated incorrectly except it was written as *wa* (see previous section 4.5), as shown by

Figure 2. On word *wianjana* by TAB, semi vowel *ia* was transliterated incorrectly except it was written as *ya* (see previous section 4.5), as shown by

Figure 2. At another aspect, cluster *nj* was transliterated incorrectly by using *gantungan ja* on syllable *na*, instead on syllable *nga*. This is because there is assimilation combination on syllable *na* into syllable *nga* [22]. TAB provide replacement consonant *ñ* for consonant *n* of cluster *nj* for correct transliteration. Actually, word *wianjana* and its variations (i.e. *wyanjana*, *wiañjana*, and *wyañjana*) represent another kind of special words since they refer to one meaning and should have same transliteration. The transliteration algorithm improvement on these special words is basically the same as described on special words at previous section 4.1.

On word *madrēwe* by BAB and TAB, vowel *ē* was failed to be transliterated but both of them provide a replacement vowel *é*. On word *kawāštanin*, consonant cluster *št* were transliterated incorrectly by both of BAB and TAB. On BAB, vowel *ā* was also transliterated incorrectly. Replacing consonant cluster *št* by using consonant cluster *st* gave correct transliteration at that part of word. On TAB, replacing

consonant cluster *śt* by using consonant cluster *st* (related to syllable *sa sapa* and *ta tawa*, see previous section 4.6) gave correct transliteration result. On word *hr̥śwa* by BAB and TAB, vowel *ē* was failed to be transliterated but both of them provides a replacement vowel *é*. On word *dir̥gha*, vowel *ī* and *gha* (related to vowel sign *ulu sari* and syllable *ga gora*, see next section 4.2 and 4.6, respectively) were failed to be transliterated by BAB but if written as word *dirga*, it gave correct transliteration result. On TAB, there is no surang was used for consonant *r* (see previous section 4.2).

5. CONCLUSION

Comprehensive accuracy comparison of Latin-to-Balinese script transliteration method on two existing methods on Android mobile application. i.e. Belajar Aksara Bali (BAB), and Transliterasi Aksara Bali (TAB) has already been conducted. Through the experiment, TAB has outperformed BAB where TAB has passed over 68% (103 of 151) cases, while BAB has passed over only 39% (59 of 151) cases. Cases based on The Balinese Alphabet writing rules and examples document by Sudewa [8], as a project script committee related to the proposal by Eversen and Suatjana [1] for encoding the Balinese script in ISO.

Accuracy of Latin-to-Balinese script transliteration method can be improved significantly by taking care of thirteen kind of special words that was identified on the testing cases during the experiment. These kind of special words, i.e.: 1) The word where its vowel at the initial position was specifically transliterated by using the independent vowel. For an example: *Ak̐sara* (letter); 2) Group of words where different writing of long vowel (*ā*, *ī*, *ū*, or *ö*) refer to one meaning and should be transliterated the same. For an example: *Kādēp* (sold) – *Kadēp* (sold); 3) Group of words where different writing of vowel *ē* refer to one meaning and should be transliterated the same. For an example: *Jēro* (house) – *Jero* (house); 4) Group of words where their vowels belong to a pair of diphthong: *ai* – *ê* or *au* – *ô* should be transliterated the same. For an example: *Dai̐tya* (giant) – *Dê̐tya* (giant); 5) Group of words where different writing of *ra repa* (*rē* or *rö*) or *la lenga* (*lē* or *lö*) refer to one meaning and should be transliterated the same. For an example: *Talēr* (also) – *Taler* (also); 6) Group of words where different writing of *semi-vowels* (*ra*, *rē*, *rö*, *ua*, *la*, or *ia*) refer to one meaning and should be transliterated the same. For an example: *Briag* (laughter) – *Bryag* (laughter); 7) Group of words where different writing of *ak̐sara ṣwalalita* (*ṇa*, *dha*, *tha*, *ṭa*, *ṣa*, *śa*, *gha*, *bha*, or *pha*) refer to one meaning and should be transliterated the same. For an example: *Bhi̐sama* (decree) – *Bhisama* (decree); 8) The word where its syllable sound must be end by using miscellaneous signs (*ulu candra* or *ulu ricem*) as part of *ak̐sara modre* sign (holy symbol). For an example: *Om* (a holly letter); 9) The word where its vowel *a* at the end position can be pronounced (and written) as vowel *ē* (creating a counterpart word). This group of words should be transliterated the same. For an example: *Sēkala* (real) – *Sēkalē* (real); 10) The word where its vowel combination *ia* can be written as the vowel-consonant combination *iya* (creating a counterpart word). This group of words should be transliterated the same. For an example: *K̐satria* (warrior) – *K̐satriya* (warrior); 11) The word where its single consonant syllable and the word where its double consonant syllable actually each has a single same sound (*dwita*) for those syllables. This pair of words should be transliterated the same. For an example: *Utama* (primary) – *Uttama* (primary); 12) Foreign word. For an example: *Bank*; and 13) Group of words where different writing of assimilation combination on syllable *na* into syllable *nga* refer to one meaning and should be transliterated the same. For an example: *wianjana* (consonant) – *wyanjana* (consonant).

In general, this research contributes on a comprehensive accuracy comparison analysis of Latin-to-Balinese script transliteration method since there is no such study before in this research area. In specific, this research contributes on identification of Latin-to-Balinese script transliteration methods on mobile application (as ubiquitous learning media) and determine their accuracy and improvement possibility. In a future, this research can be used as a reference for improvement of any Latin-to-Balinese script transliteration method that can be made by taking care on thirteen kind of special words that were found during this comparison study

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